

A DIGITAL CONTROL SYSTEM FOR OPTIMAL OXYGEN TRANSFER EFFICIENCY



Arnold Schwarzenegger
Governor

APPENDIX A: PROJECT ADVISORY COMMITTEE MEETING MINUTES

Prepared For:

California Energy Commission
Public Interest Energy Research Program

Prepared By:
Southern California Edison
University of California, Los Angeles
Utility Technology Associates

PIER FINAL PROJECT REPORT

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Prepared By:

Southern California Edison
Lory Larson
Los Angeles, California 95616

Prepared For:

Public Interest Energy Research (PIER) Program
California Energy Commission

Paul Roggensack

Contract Manager

Michael Lozano

Program Area Lead

Industrial/Agricultural/Water End-Use Energy Efficiency

Virginia Lew

Office Manager

Energy Efficiency Research Office

Thom Kelly, Ph.D.

Deputy Director

***ENERGY RESEARCH & DEVELOPMENT
DIVISION***

Melissa Jones

Executive Director

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Appendix A

PAC Committee Meetings and Recommendations

A.1 Summary of all PAC Meetings

In this project, economic analyses were performed based upon the theoretical and experimental considerations. The results were compared with actual aeration costs in full-scale plants. A Project Advisory Committee (PAC) was formed to oversee the research work and provide feedback and comments on the results. The PAC members were selected to review and recommend on: 1). field testing and protocol development and 2). plant operations improvement (i.e., operators training, cleaning frequency and methods, process upgrade, etc.).

The PAC was formed with the following expert candidates:

- | | |
|---------------------|--|
| - Dave Reardon | HDR Engineering Inc., energy audits specialist |
| - Henryk Melcer | Brown & Caldwell, process designer |
| - Rod Reardon | Camp, Dresser, and McKee Inc., process designer |
| - Mike Selna | Sanitation Districts of L.A. Co., WWTP operations mgr. |
| - Keith Carns | EPRI Solutions Inc., energy specialist |
| - H. David Stensel | Univ. of Washington, Professor - Biological Processes |
| - Omar R. Moghaddam | City of L. A., Bureau of Sanitation, manager |
| - J.B. Neethling | HDR Engineering Inc., WWT technology director |
| - Shahid Chaudhry | California Energy Commission, <i>Ex Officio</i> |
| - Lory Larson | Southern California Edison, <i>Ex Officio</i> |
| - Roger Sung | Utility Technology Associates, <i>Ex Officio</i> |

A.1.1 Summary of 1st PAC meeting

After the presentation of literature background and state-of-the-art equipment chosen for this project, the UCLA research group discussed with the PAC members the following issues:

- Quantification of potential power savings:
Energy savings can be calculated based upon the reduction of oxygen transfer efficiency of fine-pore diffusers. Due to different operation conditions, the diffuser cleaning schedule is plant-specific.
- Comparison between power savings in fine-pore aerators and other existing technologies.

Oxygen transfer efficiencies of different aerators are totally different. Off-gas method only valid for fine-pore diffusers, a more complex measurement method is required for surface aerators.

- Challenges for the technology transfer:
To convince operators to measure the oxygen transfer more frequently, the new off-gas apparatus should be easy to operate.
- Cleaning schedules
The cleaning schedule can be developed by the oxygen transfer measurement. A spreadsheet has been build for this purpose.
- Hood positioning and sizing:
Bigger hood provides accurate measurement but difficult to operate. A sensitivity study of optimal hood size will be provided by UCLA research group after the protocol is built.

The UCLA research group addressed all of the above and satisfactorily answered them. PAC members' feedback input was recorded and will be incorporated into the project development phase.

A.1.2 Summary of 2nd PAC meeting

In this meeting, the presentation provided by UCLA generally reemphasized the importance of diffuser cleaning schedules. The first version field-prototype was also introduced. Discussions and comments from PAC members focused on: the economic savings of cleaning frequency; cleaning methods; and the applications of the off-gas device. PAC members were interested in UCLA Research Group's curve method for defining the cleaning frequency provided. Members also provided their data on aeration costs as references. Other practical and useful suggestions such as the flexible hood were also favorably received by the PAC members.

A.1.3 Summary of the 3rd PAC meeting

Based upon the former meetings (1st at 06/27/2005 and 2nd at 11/02/2005), PAC members are all familiar with the main purpose and background of this project. Thus in this meeting, discussions of PAC members, UCLA research group, and Southern California Edison mainly focus on how to encourage the plant managers and operators to accept the concept and techniques to monitor aeration efficiency and power cost, in addition to the effluent quality. As by Mike Selna from Sanitation Districts of L.A., an advanced Wastewater Treatment Plant operation manager: operators always focus more on water quality instead of how to process the treatment plant correctly. Several options were recommended to link the power plant to the wastewater treatment plant, including:

- A one-day-long workshop in Edison office to present the final results and show how to implement them at a plant scale. Representatives of the whole treatment community will be invited and UCLA research group will be presenting.

- Since different rates of energy costs are counted for different purpose, i.e. rate of industrial is cheaper than residential; a rebate program could be ideal to encourage the Wastewater Treatment Plants with the aeration energy monitoring system. However, this option requires good communication between power plants and treatment plants.

Questions from PAC members are all considerate and helpful. The comments will all be included in the project.

B.1 PAC Meeting Minutes

B.1 1st PAC meeting

Time: 9.30 AM – 2.30 PM, June 27th, 2005.

Location: UCLA Civil and Environmental Eng. Conference Room, 4275 Boelter Hall.

Attendees: Lory Larson, SCE project manager, *Ex Officio*

Keith Carns, PAC member

Henrik Melcer, PAC member (on remote connection)

J.B. Neethling, PAC member (on remote connection, for the first half only)

Rod Reardon, PAC member (on remote connection)

Michael K. Stenstrom, Professor, UCLA

Diego Rosso, Ph.D. Candidate, UCLA

Shao-Yuan Leu, Ph.D. student, UCLA

Roger Sung, Utility Technology Associates, *Ex Officio*

B.1.2 Presentation Summary

B.1.2.1 Introduction

Aeration costs account for a large fraction of a wastewater treatment plant (WWTP) expenditure

There exist several methods for increasing energy-efficiency in the ASP, the most important being:

- Utilization of fine-bubble aerators
- Optimization of DO control systems
- Implementation of diffuser maintenance/cleaning schedules

B.1.2.2 Project Objectives

- investigate the economic saving of cleaning frequency for fine-pore diffusers
- build lab-scale and field prototypes of OTE measuring devices
- extensively test them on several WWTPs
- build small-scale capture hoods
- develop a field testing protocol for operators
- create aerators' cleaning/maintenance schedules and protocols
- utilize the OTE measurements for a process economic analysis

B.1.2.3 Project Approach

Goals of this project are to develop an oxygen transfer efficiency monitoring device. Formation of professional advisory committee (PAC), lab-scale experiments, and field-scale prototype were developed for this purpose.

B.1.2.4 Project Outcomes

- PAC was formed to revise the research work and give feedback and comments on the results
- Two off-gas apparatus which will be used to develop the field-scale prototype were tested and demonstrated in PAC meeting

B.1.2.4 Conclusions and Recommendations

- Until now, 20% of the works have been accomplished
- The future work will focus on laboratory-scale experiments related to measuring gas transfer efficiency and developing new versions of field-scale prototype

B.1.3 Minutes of the discussion

*1. **Henrik Melcer:** Is the core of the instrument a fuel cell? If so, what's the operating principle?*

Michael Stenstrom: The core of the instrument is indeed a fuel cell, and the operating principle is as follows. The air mixture facing the cell diffuses through the porous membrane into the fuel cell, where oxygen will be consumed (as fuel) in an electrochemical reaction, which will produce a voltage. This voltage is recorded by a device connected to a computer. Known the composition of the air mixture (20.95% of oxygen, in standard conditions), the voltage can be immediately converted to a oxygen partial pressure scale.

*2. **J.B. Neethling:** How easy do you expect to be the installation of such a monitoring apparatus in a wastewater treatment plant?*

Michael Stenstrom: The hood size will be reduced from the manual, traditional off-gas testing, and the hood will be stationed in a fixed position. Also, the main goal of this study is to produce a simple, economical, operator-proof instrument. In the second part of this study, the field-scale testing, we will work together with plant operations in selected locations, to include all the operators' feedback. This will maximize the user-friendliness of this system.

*3. **Henrik Melcer:** What actions can WWTP staff take to improve the efficiency of their aeration system?*

Diego Rosso: In the final part of this project, the technology transfer, we will include the outcomes of our recently published papers on aerators' efficiency and ageing in the

tutorial seminars. Moreover, the results of our previous investigations will be transmitted to the wastewater treatment community in form of sample calculations and procedures.

Lory Larson: Also, at the very end of the project, we will host a day-long workshop in our Edison office where we will invite representatives of the whole treatment community. Mike, Diego, and Ben will then present their final results and show how to implement them at a plant scale.

*4. **Keith Carns:** Can you directly connect the fuel cell to a computer and read the oxygen concentration?*

Michael Stenstrom: Yes, the cell can be wired directly into a computer interface, thus bypassing the oxygen purity meter instrument. This simplifies the apparatus and has the big advantage to considerably reduce size and costs. (Follows a demonstration of a working oxygen fuel cell, performed by Diego Rosso)

*5. **Henrik Melcer:** Do you know yet how your proposed device will be calibrated, assuming that it will require calibration?*

Diego Rosso: one of the main features of this device is self-calibration, included in the design to simplify the operations of the device as much as possible.

*6. **Henrik Melcer:** If you permanently mount a hood in one location on an aeration tank, do you think you'll be able to develop approximate ratios between the measured OTE at that location and the overall tank efficiency? How many variables might affect such a ratio? Or will this have to be measured for each tank?*

Michael Stenstrom: hood positioning and sizing will be addressed in the field-scale sensitivity analysis included in the development of testing protocol, in 2006.

*7. **Henrik Melcer:** If OTE decays gradually over a period of years, is there any advantage to monitoring OTE continuously?*

Diego Rosso: The advantage of monitoring OTE continuously is that the rate of reduction in OTE is site-specific. We have collected an average rate of OTE decline over time for different operations (i.e., conventional, nitrification-only, nitrification/denitrification) and for different diffusers time in operation (new, used within 24 months, old over 24 months, cleaned within 1 month) and published them in our recent paper, Economic Implications of Fine-Pore Diffuser Ageing.

Michael Stenstrom: Field testing on a specific location provides the accurate OTE rate of decline value necessary for the economic analysis and the calculation of cleaning frequency.

B.2 2nd PAC Meeting

B.2. Background

Time: 0130~0330 PM, November 2, 2005.

Location: WEFTEC conference hotel, Renaissance Washington DC Hotel, room 17.

Attendees: Lory Larson, project manager

Michael Selna, PAC member

Keith Carns, PAC member

Omar R. Moghaddam, PAC member

Rod Reardon, PAC member

Michael K. Stenstrom, Professor, UCLA

Diego Rosso, Postgraduate Researcher, UCLA

Shao-Yuan Leu, Ph.D. student, UCLA

B.2.2 Presentation Summary

In this meeting, the detailed aeration cost analysis and primary results of lab-scale tests were presented. The 1st version field-scale prototype was also introduced. Possible testing methods were also discussed by PAC members. The presentation outlines were as follow:

B.2.2.1 Introduction

Aeration costs account for a large fraction of a wastewater treatment plant (WWTP) expenditure

There exist several methods for increasing energy-efficiency in the ASP, the most important being:

- Utilization of fine-bubble aerators
- Optimization of DO control systems
- Implementation of diffuser maintenance/cleaning schedules

B.2.2.2 Project Objectives

- investigate the economic saving of cleaning frequency for fine-pore diffusers
- build lab-scale and field prototypes of OTE measuring devices
- extensively test them on several WWTPs
- build small-scale capture hoods
- develop a field testing protocol for operators
- create aerators' cleaning/maintenance schedules and protocols
- utilize the OTE measurements for a process economic analysis

B.2.2.3 Project Approach

Goals of this project are to develop an oxygen transfer efficiency monitoring device.

Formation of professional advisory committee (PAC), lab-scale experiments, and field-scale prototype were developed for this purpose.

B.2.2.4 Project Outcomes

- PAC was formed to revise the research work and give feedback and comments on the results

- Three laboratory-scale experiments related to measuring gas transfer efficiency and testing off-gas apparatus were accomplished
- Field-scale prototype v.1 has been built, which the size is about half of the initial one

B.2.2.5 Conclusions and Recommendations

- Until now, 50% of the works have been accomplished
- The future work will focus on developing new versions of field-scale prototype and sensitivity analysis of hood size

B.2.3 Minutes of the discussion

1. **Mike Selna:** *Your main goal will be to convince operators to clean the diffusers more often. Although the cleaning frequency can be varied depending on each case, it is generally concluded that fine-pore diffusers should be cleaned at least once per year.*

Diego Rosso: (A powerpoint slide is projected in this instance) A method to define the cleaning frequency for fine-pore diffusers in ASP was published by Rosso and Stenstrom (2005b and 2005c): Figure 8 shows the generalized results of the economic analyses for a longer range of time in operation. Each curve is labeled according to off-gas test results. The upper-half of the graph shows the evolution over time of the ratio of actual power to initial power, i.e., the dimensionless power waste. The bottom-half plots the power waste to cleaning cost ratio versus time in operation. The characteristic saw tooth shape describes the evolution of costs over time. As the time in operation increases, the power waste to cleaning cost ratio grows and when it approaches 1, the algorithm sets a cleaning event with a steep decline in cost. An excel spreadsheet is provided to develop a specific curve for treatment plants.

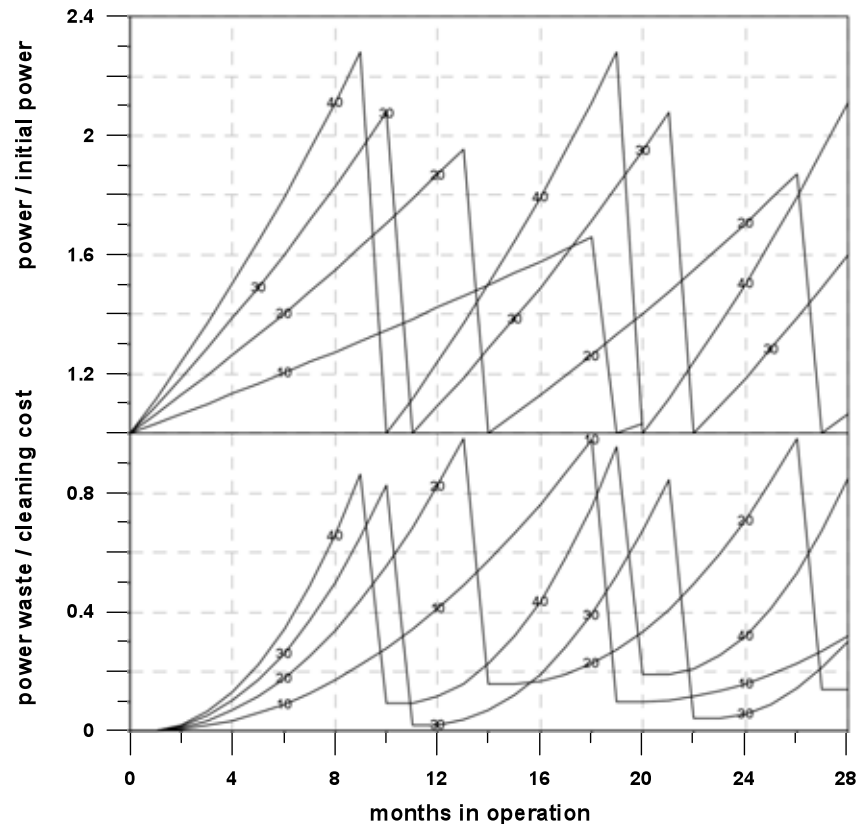


Fig. 8. - Dimensionless cost ratios versus time in operation.

2. **Keith Carns:** *It is mentioned in the presentation that after cleaning the performance of fine pore diffusers recovers only around 80% of new or the latest cleaned ones. If this reduction can be accumulated, the performance of diffusers would be continuously decreased with time, even regular cleaning is provided.*

Diego Rosso: Over the lifespan of the membranes, the reduction of performance is inevitable, because some of the severely fouled/scaled pores can not be cleaned. No membrane can recover to efficiency values comparable to new ones. Appropriate operations and cleaning management is helpful to increase the efficiency recovery and the overall diffuser lifespan. There exists a point in the lifespan of the diffusers where the recovery does not meet a sufficient value for operations, and the diffusers must be replaced. In order to quantify this turning point in time it is necessary to monitor the efficiency on-line for a prolonged time (i.e., months or years), which is one of the aims of this project.

3. **Omar Moghaddam:** *What's the general performance of acid cleaning (for both liquid and gas)?*

Michael Stenstrom: Acid cleaning has shown better improvement on transfer efficiency and pressure loss than tap water cleaning. It is explained by the higher solubility in acid for some inorganic scaling compounds. Nevertheless, there may be a degradation of membrane properties. In our current database we have no significant number of facilities where acid cleaning.

Diego Rosso: At this point, however, in our dataset we do not have an amount of data pertaining acid cleaning experiences large enough to quantify a difference.

4. **Michael Selna:** *Since the off-gas instrument can be set up as a permanent device for treatment plants, is it possible to develop a feed-back control system based upon off-gas readings?*

Diego Rosso: An off-gas device is a tool to assess the long-term performance of operating diffusers. Continuous off-gas monitoring may complete the information understanding the dynamic treatment status in the aeration tank. Therefore, a final goal of returning feedback to the aeration control system would be optimal.

5. **Rod Reardon:** *What would be the appropriate hood size?*

Michael Stenstrom: In general, the hood reflects the performance of diffusers underneath its surface. Larger hoods provide information for more diffusers but are also more difficult to operate. Smaller hood is easier to operate but only collect the air sample from a smaller area of the tank, which is not representative to the whole tank. In this project, a movable minimum size hood will be investigated and designed. The mobility of the hood provides us the spatial information of diffusers and the whole-tank performance can be estimated by integration.

6. **Michael Selna:** *Aeration costs of \$7.5 million/year and \$110/million gallons are average, reasonable estimates for our county plants. How do they compare to theoretical values?*

Michael Stenstrom: The recent paper we published, regarding economic analysis of conventional, nitrifying-only, and nitrifying/denitrifying operations returned results that can be roughly summarized as: \$48/million gallons, \$56/million gallons, and \$36/million gallons for conventional, nitrifying-only, and nitrifying/denitrifying process, respectively. We will check the calculation assumptions that we used for this study and will discuss in the coming meeting the results.

B.3 3rd PAC Meeting

B.3.1 Background

Time: 10.00 AM – 12.00 PM, June 28th, 2006.

Location: Conference call.

Attendees: Lory Larson, project manager, *Ex Officio*

Shahid Chaudhry, California Energy Commission, *Ex Officio*

Keith Carns, PAC member, EPRI Solutions Inc., *energy specialist*

Henrik Melcer, PAC member, Brown & Caldwell, *process designer*

Mike Selna, PAC member, LA Sanitation Districts, *WWTP operations mgr*
Fred Yunt, Sanitation Districts of LA.
Roger Sung, Southern California Edison, *Ex Officio*
Michael K. Stenstrom, UCLA, *Professor*
Diego Rosso, UCLA, *Postdoctoral researcher*
Shao-Yuan Leu, UCLA, *Ph.D. student*
Pan Jiang, UCLA, *Ph.D. student*

B.3.2 Presentation Summary

B.3.2.1 Introduction

Aeration costs account for a large fraction of a wastewater treatment plant (WWTP) expenditure. Utilization of fine-bubble aerators increases energy-efficiency in the activated sludge process (ASP), but it requires implementation of diffuser maintenance/cleaning schedules. The goal of this project is to develop an oxygen transfer efficiency monitoring device for those fine-pore diffusers.

B.3.2.2 Project Objectives

- Investigate the economic saving of cleaning frequency for fine-pore diffusers
- Build lab-scale and field prototypes of OTE measuring devices
- Develop a field testing protocol for operators
- Create aerators' cleaning/maintenance schedules and protocols
- Utilize the OTE measurements for a process economic analysis

B.3.2.3 Project Outcomes

- Two field prototypes (version 1.0 and 2.0) have been built. The presentation introduced the design of two versions of field-prototype.
- A lab-scale experiment was performed to test the apparatus
- Two field experiments testing the prototypes were accomplished, one in Simi Valley and the other in Chino, Inland Empire. A video was filmed from the test in Chino, Inland Empire, to show the design of new analyzer and how an off-gas test was accomplished.

B.3.2.4 Conclusions and Recommendations

- Until now, around 70% of the works have been accomplished
- The future works will be continue testing the new field-scale prototype and perform the hood size analysis.

B.3.3 Minutes of the discussion

1. Henrik Melcer: According to the description in slide #9, is the lab-scale experiment comparable to field-prototype?

Michael Stenstrom: Yes. The lab-scale test is designed to test the apparatus used in the field-prototype. The basic theories of lab- and field- scale tests are the same.

2. Lory Larson: *What's MLE?*

Diego Rosso: Modified Ludzack-Ettinger process, i.e. the simplest layout exploiting nitrification-denitrification.

3. Henrik Melcer: *What's happening to the 2nd part of the aeration basin in the treatment plant, Simi Valley, shown in the graph in slide #11?*

Diego Rosso: The second tank is a polishing basin from the old system. The tanks are shallower but equipped with the same type of diffusers as the processing tanks.

Michael Stenstrom: It is not a regular design. The plant is planning to change it to provide better treatment performance.

4. Henrik Melcer: *According to the picture in slide #18, is it possible that the floating hood can impact the surface aeration? Which diffusers are in place in Chino?*

Michael Stenstrom: In most of the aeration tanks using fine-pore diffusers, the transfer from water surface is negligible comparing to the aeration from bubbles. Polyurethane membrane diffusers are used in the plant and there is no MLE pump in this system.

5. Henrik Melcer: *In the figure of slide #3, what are the numbers, 7%, 12%, and 11% represent? Those numbers seems too low if they are the OTEs of treatment plant of Chino.*

Diego Rosso: Those are average OTEs adapted from the former experiment results. The detailed of this study was shown in our paper (2005b), which compiled the 15-year off-gas test results from treatment plants in California.

6. Shahid Chaudry: *The job reducing the size and complexity of off-gas test must be encouraged. What are the other sites?*

Michael Stenstrom: LA City's Tillman and Glendale, LA County's Whittier and San Jose Creek, and the Central Plant of Contra Costa County in Northern California.

7. Mike Selna: *How do you document the cleaning frequency based upon the type of operation process? Is there any difference of the cleaning procedure between MLE and step-feed process?*

Michael Stenstrom: The cleaning age of diffusers in Simi Valley is 6 month. One of the two aeration basins of Chino treatment plant is 1 year and the other is 1 month. Parallel tests may be performed to compare the effects of age of cleaning and develop the cleaning schedule.

Diego's paper: The design of cleaning schedule is site specific. In general, the alpha SOTEs as shown in our papers (2005a and b) are 1.1% to 0.7% to 0.6% from new, clean, and old, respectively. With higher SRT and better bacteria composition, the diffuser condition of NDN process is generally much better than conventional treatment plant with low SRTs.

Michael Stenstrom: After 2 year's operation the transfer efficiency reduced to about half.

8. Henrik Melcer: *How can we convince the operators to do oxygen transfer tests and establish a proper cleaning schedule, since everybody has a tight budget?*

Michael Stenstrom: Linking the power plant to wastewater treatment plant may encourage plant manager to focus on the issue of energy saving.

Lory Larson: At the very end of the project, we will host a one-day-long workshop in our Edison office where we will invite representatives of the whole treatment community.

Mike, Diego, and Ben will then present their final results and show how to implement them at a plant scale.

*9. **Keith Carns:** What's the regulation from EPA on aeration costs of wastewater treatment? Could energy efficiency testing added to the regulation requirements? Is it possible to provide a discount or rebate program on energy costs to the plant accomplishes the OTE monitoring program?*

Lory Larson: Different rates of energy costs are counted for different purpose, i.e. rate of industrial is cheaper than residential. Rebate program is possible but it requires better communication between power plants and treatment plants.

Diego: In some large municipalities, such as the City of LA, there is no way to track the source of energy consumption, since different entities perform operations and record expenses.

Mike Selna: Yes. Operators always focus more on water quality instead of how to process the treatment plant correctly.